Analysis of Safety Effectiveness for Removing/Relocating Fixed Objects and Installing Median Barriers

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Analysis of Safety Effectiveness for Removing/Relocating Fixed Objects and Installing Median Barriers

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Abstract

Analysis of Safety Effectiveness for Removing/Relocating Fixed Objects and Installing Median Barriers

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This report presents the methodology to develop Crash Reduction Factors (CRFs) for the two improvement categories: 1.Remove/Relocate Fixed Object and 2. Install Median Barrier. A CRF of a treatment site is the percentage of crashes reduced from a site after the particular treatment received. They are used to estimate cost benefits due to reduced crashes. The most of the studies develop CRF values by using a simple before-after method. In such a method, it cannot address the 'Regression-to-the-Mean' bias.

In this study, Empirical Bayes (EB) method is used to address the 'Regression-to-the-Mean' bias in developing CRFs. The crash, geometric and traffic data were collected for both treatment and comparison sites from the Ohio Department of Transportation (ODOT). PROC GENMOD model in Statistical Analysis System (SAS) was used to compute the parameters, which are the mean and variance of the Negative Binomial (NB) distribution for both treatment and comparison sites. CRF was calculated with ratio of the

EB estimate of crashes after period of treatment, if no treatment had been applied to the observed crash count for a treatment site in the after period.

The CRF values calculated for the two improvement categories are as follows -

1. Remove/Relocate Fixed Object
   - All crashes: 38.23% decrease in crashes with a standard error estimate of ±10.30%
   - Injury/Fatal crashes: 38.13% decrease in crashes with a standard error estimate of ±13.40%
2. Install Median Barrier
   - All crashes: 86.33% decrease in crashes with a standard error estimate of ±2.92%
   - Injury/fatal crashes: 88.37% decrease in crashes with a standard error estimate of ±5.23%

This study was limited in terms of the number of treatment and comparison sites because of the available data at the time of the research. By adding more treatment and comparison sites, the estimates for CRF's could be more precise.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

As the number of vehicles and vehicle miles of travel increased throughout the United States, the exposure of the population to traffic crashes also increased. In 2003, a total of 43,200 people were killed in highway crashes in the United States, a slight rise of 0.9% from 42,815 in the previous year (Bureau of Transportation Statistics). This cost the nation billions of dollars every year making highway safety a prime concern in the United States. The Federal Highway Authority (FHWA) is making efforts to reduce the crashes on the highway. FHWA has developed the highway safety improvement program (HSIP) with the overall objectives of reducing the number and severity of crashes. The HSIP consists of three components: 1) Planning 2) implementation and 3) Evaluation. The Intermodal Surface Transportation Efficiency Act (ISTEA) enacted in 1991, requires the states to develop, establish and implement program for HSIP.

The main purpose of a safety improvement is to reduce the number and severity of crashes. It is important to know the effectiveness of the safety improvement in sites to allocate resources optimally. The effectiveness of safety can be measured in a number of ways. One such tool for measuring is benefit/cost analysis. The Crash Reduction Factors (CRFs) are used in developing the benefit/cost ratios. CRF is the percentage of crashes that are eliminated from the site, after the treatment is received. CRF are used to prioritize the most effective safety improvement measures.

The Ohio Department of Transportation (ODOT) maintains a complete list of highway crash locations and crash reduction factors. It is important to verify and update these CRF's periodically to ensure their accuracy.

Usually before-and-after studies are used to develop CRF's. A before-after study consists of four steps:

- The first step is site selection; study sites with sufficient crash data for before and after periods of construction should be selected.
- The second step is data collection and preparation of geometric features, Traffic volumes and crash history should be collected for all of the sites. Also, sites with similar safety improvement can be grouped together.
- The third step in the before-after study process is the crash frequency estimation.
- The fourth and final step in the process is the comparison and statistical analysis of the before-and after data.

There are potential problems involved with simple before and after analysis. The main problem with simple before and after analysis is that the treatment sites may experience low crash even if no treatment had been made. This may be due to driver behavior, weather conditions, and change in geometric design etc. This phenomenon is known as 'Regression- to-the-Mean' bias. The objective of this thesis is to develop CRF for the following two improvement categories:

- **Relocate/Removal of fixed object:** The removal of an object that is adjacent to the roadway or the relocating a object to a safe distance from the roadway. These objects shall include utility poles, trees, guardrails, sign supports and fire hydrants.
- **Install median barrier:** Installation of new concrete barriers in the median.

Each improvement category is further discussed in detail in the following sections.

1.2 Relocate/Remove fixed object

Figure.1 Fixed Object Crash

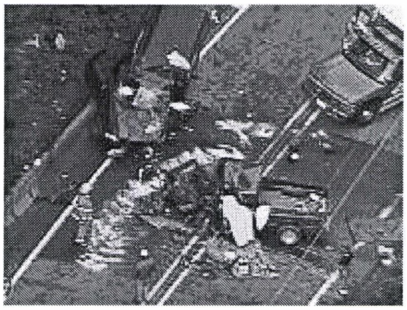
(Source: highwaysafety.utah.gov/.../ report/police.html)

Fixed objects are rigid objects, which are located near to the road. When an uncontrolled vehicle runs off the road, the fixed object may become a hazard to the vehicle. A common fixed object includes utility poles, trees, ornamental mailboxes etc. complete removal of these objects may be expensive but it is a safe countermeasure.

This improvement should be considered for any run-off the road crashes where a vehicle impacted by a fixed object.

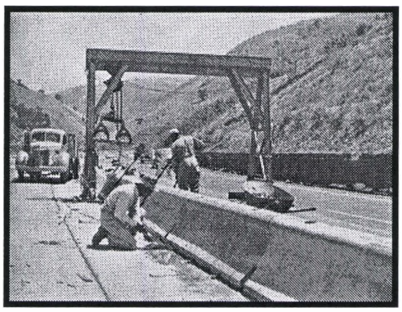
1.3 Install Median Barrier

Figure.2 Median Type Crash



(Source: www.kirotv.com/traffic/ 2553801/detail.html)

Figure.3 Installing Median Barrier on Highway



(Source: www.gbcnet.com/.../ US99/US99g_contents.html)

The median crashes have been identified as a national problem due to the severity involved. This type of crashes occurs when uncontrolled vehicle crosses the median and enter the opposing lanes of travel. One method to reduce the severity of these crashes is to install a median barrier. Median barriers are solid structures constructed along the centerline of a road so as to block through movement at a cross street. Median barriers make highway safer by:

- Preventing uncontrolled vehicle penetration
- Redirecting uncontrolled vehicles to a direction parallel to traffic flow
- Minimizing hazard to vehicle occupants during collision

The first concrete median barriers were used in the mid-1940 on US-99 on the descent from the Tehachapi Mountains in the central valley south of Bakersfield, California (http://www.roadstothefuture.com/Jersey_Barrier.html). The first generations of concrete barriers were developed to minimize the number of out-of control trucks penetrating the barrier.

1.4 Organization of thesis

The following are the chapters that are discussed in this thesis:

- Chapter-2: Literature Review- describes prior research conducted to establish CRF's.
- Chapter-3: methodology- describes the method of analysis to develop CRF's for given improvement categories.
- Chapter-4: data collection- gives details about site selection, data collection and execution.
- Chapter-5: Statistical modeling- describes statistical modeling and calculation for CRF's.
- Chapter-6: Conclusion- presents conclusion of the study.

CHAPTER 2

Literature review

2.1 Literature review

This chapter presents a literature review on "CRASH REDUCTION FACTORS".

Kentucky Department of Transportation, (KTC-96-13) [Agent, et al., 1996]

In this study, a survey of states on their use of CRF's was conducted. Forty-three states and the District of Columbia responded to this survey. Of these forty-four responses, thirty-seven use some type of crash reduction factor in their safety improvement program. From thirty-seven states, nineteen have developed their own crash reduction factors while the remaining eighteen used crash reduction factors from the other sources.

Development of South Dakota Crash Reduction Factors, (SD98-13-F) Final Report. [Tople et al., 1998]

South Dakota Department of transportation investigated sixty-two hazard elimination and safety projects (HES) located throughout the state of South Dakota. Before- and- after crash data was collected for a six-year range (1984-1990) to develop the crash reduction factors (CRF's). The CRF's were developed for 17 improvement categories, but only 14 are found to be precise. The Microsoft access ™ database was implemented to estimate CRF values. South Dakota compared this list of CRF's with those used by Kentucky, New York, California, and FHWA. The CRF's improvement categories like traffic signal, reconstruction of left turn lane, roadway lightning, and pavement marking for left turn lane were shown similar values when compared to other states.

Crash Reductions following installation of roundabouts in the United States, Ryerson Polytechnic University Toronto, Ontario, March 2000.

This study was conducted to estimate crash reduction factors for the installation of modern roundabouts in the United States. Eight states were considered for the analysis (California, Colorado, Florida, Kansas, Maine, Maryland, South Carolina and Vermont), where a total of 24 intersections were converted from stop sign and traffic signal control to modern roundabouts. A before-after study was conducted using the Empirical Baye's approach, which accounts for regression to the mean. Results showed 39% percent reductions of all crashes and 76% reduction for all injury crashes for the 24 converted intersections. Overall, results showed consistent to international studies and suggest that roundabout installation should be strongly promoted as an effective safety treatment for intersections.

Procedures for estimating accident reductions on two-lane highways, Journal of Transportation Engineering, Vol. 118, January/February 1992.

This study developed crash reduction factors for two-lane rural highway in Illinois. Crash prediction models and a before-and-after study were used to estimate crash reduction factors. Crash data for two years before and two years after the improvement were collected from 51 projects. One linear and multiplicative form models were used to feed the accident data. The linear model was found to be better and in some cases, even better than multiplicative models in explaining the variation of the accident frequency in both before - after conditions. The linear model showed a strong correlation between crash frequencies, traffic volume and roadway geometry than the multiplicative models. The before and after study with control sites showed crash reductions were more than those of the linear model.

Safety Effectiveness of Intersection Left-and Right –Turn Lanes, FHWA-RD-02-089 (3). [Harwood, et al., 2002]

This report presents the results of a before –after evaluation of the safety effects of providing left and right turn lanes to unsignalized and signalized intersections, and extending the length of existing turn lanes. Three methods of before/after studies were compared. The three methods were:

- Before-and –after evaluation with yoked comparisons
- Before-and –after with a comparison group

- Before-and-after with the Empirical Baye's approach

Improvement types were selected such that sufficient numbers of improvement sites were available for analysis. The improvement categories selected were: adding left turn lanes, adding right turn lanes, adding both left and right turn lanes, extending an existing left or right turn lane. The following three types of sites were considered for analysis.

- Improved or treatment sites, which were intersections at which a particular improvement was implemented.
- Comparison sites (where no improvements were implemented), which were intersections more or less similar to treatment sites characteristics.
- Reference sites (where no improvements were implemented), which were intersections not matched to any particular improved sites.

Geometric design and traffic control, volume and accident data were collected for a total of 280 improved sites, as well as 300 similar intersections that were not improved during the study period.

Before-after comparison with yoked comparison (YC), involves a one-one matching between improved sites and comparison sites. The YC approach has three major weaknesses. First, it cannot handle the variation of traffic volume and crash reduction estimates are computed with relatively wide confidence limits. Second, the YC approach cannot deal with the phenomenon of 'Regression- to the- Mean' bias. Third, it has difficulty in dealing with crash frequency with value equal to zero.

Crash reduction factors were found for three and four lane intersection with and without traffic signals in rural and urban areas. The report recommended the use of EB approach to offset the presence of 'regression-to- the mean'.

The Evaluation of Safety Effectiveness on California state highways, CALTRANS report. [Reed et al., 1998]

California Department of Transportation (CALTRANS) used crash reduction factors (CRF's) to assist in the calculation of traffic safety index values, which are then used to prioritize safety improvement projects on California State highways. CALTRANS reviewed four CRF's (i.e. Rumble strip installation, shoulder widening, super elevation correction and curve correction) that were in use for the last 30 years and developed a CRF for wet pavement improvement. Crash data was collected for three years before and after for each site and CALTRANS used Empirical Bayes technique to find CRF's which address the 'Regression- to- the Mean' bias. A specialized computer program, Bayesian Estimation of Crashes in Transportation Studies was developed to aid in the crash analysis. From the five treatment categories only the following were found statistically better to support their adoption. The results of study were:

Rumble Strip Installation: 15 percent Reduction in crashes

Shoulder Widening: 15-30 percent Reduction in crashes

Wet Pavement: 30 percent Reduction in crashes

Analysis of Design Attributes and Crashes on the Oregon Highway System, Final Report. (OR-RD-02-01), Final Report [Strathman et al., 2001]

An investigation of the statistical relationship between crash activity and roadway features on the Oregon state highway system was conducted in this study. Crash models were estimated based on functional classification (freeway vs. non-freeway) and location (urban vs. rural). A number of highway features were found to be statistically related to crash activity in the various models including the number of lanes, curve characteristics, vertical grade, surface type, median type, turning lanes, shoulder width and lane width.

11,365 highway segments were considered to collect the data from the Oregon Department of Transportation (ODOT) Integrated Transportation Information System (IITS). IITS roadway inventory consists of:

a) Roadway identification

b) Number of lanes

c) Posted Speed limit

d) Surface width-right and left shoulder width

e) Surface composition, right and left turn lanes

f) Median type

g) Urban-non urban locations and

h) Average daily traffic (ADT)

Negative binomial estimation, zero inflated negative binomial estimation, and the countermeasure analysis tool (CAT) software was used to analyze crash reduction factor. The CRF's from the crash models were then compared to those found from the software. A range of CRF's were developed for the following categories:

a) Installation of a curbed median on an urban non-freeway

b) The installation of a vegetation median on an urban freeway

c) The installation of a left-turn lane at an unsignalized intersection on a rural Non-freeway

d) The widening of the shoulder (0-8 ft) on an urban or rural non-freeway.

The valid crash models clearly distinguished variables related to high cost countermeasures. This study valid CRFs that were considered as reasonable countermeasures. CAT CRFs were calculated using before and after studies, and the crash model CRFs were calculated using highway design attributes.

Fatal Crashes on Rural Secondary Highways, (FHWA-SC-03-04) Final Report. [Clark et al., 2003]

This study was conducted to investigate the over representation of crashes in South Carolina (SC). A comprehensive data set was collected for 157 randomly selected fatal crashes. Four categories of data set (environment, crash details, vehicle details and involved persons) were collected from SC state and Federal agencies and converted into the required form. A set of thirty countermeasures was selected to develop CRF's.

Bayesian Statistical Analysis Framework (B-SAF) was used to analyze the crash data. It combines expert knowledge and the empirical knowledge to evaluate the safety effectiveness of selected improvement type. The assessments of selected improvements by experts and distribution developed for empirical data when both organized together formed 'priori' distributions and estimated more accurate effects of the improvement proposed.

A team of five safety experts was selected by South Carolina Department of Transportation (SCDOT) to develop a prior distribution for the effectiveness of each improvement type. A literature survey was conducted to identify CRF values for each of the selected improvement types. Combining the distributions of the prior and likelihood values produced the posterior CRF for each improvement type.

.Iowa Department of Transportation, CTRE Project (00-61), Ames, Iowa. [Thomas et al., 2001]

The study was conducted on 7 improvement categories. For the five of these categories, crash reduction factor and benefit /cost ratios were found by collecting crash data from three years before the improvement and three years after the improvement. A total of 94 locations were selected for the project.

This report discusses the phenomena of RTM and suggested several other methods to reduce the bias of the analysis. It was finally concluded that RTM would not significantly impact the results of the study. Iowa Department of Transportation conducted a simple before-and –after study and CRF's were developed for total crashes and for specific crash types. The following CRF's were considered:

New traffic signal: 28% reduction

New signal with new turn lanes: 20% reduction

Replace pedestal with mast arms: 36% reduction

Add turn lanes: 12% reduction

2.2 Remove/Relocate Fixed Objects

This improvement type includes the removal of an object that is adjacent to the roadway. These objects shall include utility poles, trees, guardrails, sign supports and fire hydrants.

2.2.1 Relocate Fixed Object

The following are the literature reviews studied on the relocation of fixed objects.

Kentucky researchers recommended the following CRF's for the relocation of fixed objects. It was based on the combined estimates resulting from a survey of 43 states plus the District of Columbia and a comprehensive literature review.

Table 1: Recommended Crash Reduction Factors for Relocate Fixed Object, (KTC-96-13)

Type of Improvement	Percentage Crash Reduction Factors (CRF's)
Relocate fixed object:	
All Crashes	25
Fatal Crashes Only	40
Injury Crashes Only	25

Kentucky's study "Development of Accident Reduction Factors" (Creasy and Agent, 1985) which was based on a combination of literature review, 22 state surveys and a before-after analysis provided the estimation that a 40 % reduction should occur in fatal crashes due to the relocation of fixed objects, and a 15% reduction should occur in injury only crashes after relocation of fixed objects.

The following were the estimated result of CRF's for Remove/Relocate Fixed Object, which were provided by FHWA (Smith et-al, 1983) at locations where fixed objects were either removed or relocated:

Table 2: FHWA Fixed Object Relocation Crash Reduction Estimates

Type of Improvement	Mean Percent Crash Reduction Factors (CRF's)
Remove/Relocate fixed object:	
All Crashes	60
Fatal Crashes Only	65
Injury Crashes Only	60
Property Damage Only	55

2.2.2 Remove Fixed Object

The following are the literature reviews studied on the relocation of fixed objects.

Kentucky researchers recommended the following CRF's for the remove of fixed objects

Table 3: Recommended Crash Reduction Factors for Remove Fixed Object, (KTC-96-13)

Type of Improvement	Percentage Crash Reduction Factors (CRF's)
Remove fixed object:	
All Crashes	30
Fatal Crashes Only	50
Injury Crashes Only	30

Based on Kentucky study "Development of Accident Reduction Factors" (Creasy and Agent, 1985) which was based on a combination of literature review, 22 state surveys and a before-after analysis provided the estimation that a 50 % reduction should occur in fatal crashes due to the remove of fixed objects. Similarly a 15% reduction should occur in injury only crashes after relocation of fixed objects.

South Dakota Department of Transportation (SDDOT) compared the CRF's values with those of Kentucky, New York Department of Transportation (NYDOT), and Federal Highway Administrative (FHWA). The table below shows a comparative CRF's values for remove fixed object improvement.

Table 4: A Comparative Table Showing CRFs for 'Remove Fixed Object' (Report no. SD98-13-F)

State	Average CRF's (%)
South Dakota	100.00
University of Kentucky	30.00
NYDOT's	17.00
FHWA	22.00

2.3 Install Median Barrier

The following are the literature reviews studied on the relocation of fixed objects.

Kentucky researchers recommended the following CRF's for the Install Median Barrier.

Table 5: Recommended Crash Reduction Factors for Install Median Barrier, (KTC-96-13)

Type of Improvement	Percentage Crash Reduction Factors (CRF's)
Install Median Barrier:	
All Crashes	5
Fatal Crashes Only	65
Injury Crashes Only	40

2.4 Literature Review Summary

The concepts of crash reduction factor were started in 1970's for prioritizing safety improvement programs in a systematic manner. Various methods were implemented to evaluate highway safety improvements at high crash locations.

The crash reduction factor is a measurement of the percentage of accidents that will be reduced as a result of deployment of a given safety improvements. A review of literature related to this topic has yielded the following conclusions as the methodology:

- The simple before-after studies, failed to account for 'Regression-to-the-Mean' bias.
- Empirical Bayesian method can be used to account for 'Regression-to-the-Mean' bias.

CHAPTER 3

METHODOLOGY

3.1 Methodology

As discussed in chapter 2, most of the studies developed CRF values by using a simple before-after method. In such a method, the assumption for estimating the expected frequency of crashes in the before period was that for any treated site, the count of the before crashes, K, is a sensible estimate of its expected crash count. In observational studies this may be untrue. The treatment sites may experience low crash even if no treatment had been made. This may by because of driver behavior, weather conditions, change in geometric design etc. This phenomenon is known as 'Regression- to-the-Mean' bias. It makes λ a biased estimate of K.

The regression to mean phenomenon can be explained quite simply. The sites chosen for the treatment, may have experience many or few crashes in the past. Because of the unusual past crash history, is difficult to hope that the unusual is a good basis for predicting the expected crash count in the after period, if no treatment been applied.

To estimate normal and usual crashes by using crash counts that are abnormal or unusual, may lead to an obvious bias. If the site has been selected because it had unusually high crash rate, K would tend to overestimate λ.

To compensate 'Regression-to-the-Mean' bias, Empirical Bayes (EB) approach is used to calculate CRF values in this study. EB approach has the following advantages:

- The EB approach helps to deal with the 'regression- to- the- mean' bias.
- EB estimates tend to be more precise than the other before- after studies.
- The EB approach allows the estimation by the entire time series k_1, k_2, k_3 ...... as required.

There are two kinds of criteria to the safety of a treated site:

- The first kind of criteria contains the characteristics of a site such as geometric data, severity of crash and traffic data.
- The second kind of the safety of a site is derived from the history of crashes

The fundamental nature of the EB approach is to use both criteria for the safety estimation. These two criteria have to be combined to prepare the procedure for calculating CRFs. Criteria of the first kind enable to make informative statement of safety of a specific treatment site only if some knowledge exists about the safety of a group of site with similar characteristics. This group of sites with similar characteristics is called the 'comparison sites'.

The distribution of crashes is often distorted in that the most sites experience few crashes while a small number of sites experience relatively many more crashes. The Poisson distribution is best suited when dealing with rare discrete random events such as crashes. In a Poisson distribution the magnitude of variance is equal to the mean. The relationship between mean and variance is often desecrated for crash counts due to natural overdispersion in crash data (i.e., the variance of crash count usually exceeds the mean). To overcome this problem the negative binomial distribution is used in this study. The negative binomial distribution has two parameters, the mean and dispersion parameter. Generally the variance for the negative binomial is larger than the mean. When dispersion parameter approaches zero, the negative binomial distribution becomes the Poisson distribution.

Negative binomial distribution is not practical to estimate the mean and variance; the characteristics of the control sites (i.e., ADT, lane width, trucks etc) may not be same with the treatment sites, Multivariate-modeling approach is used in this study to address the problem.

The general form for the model in negative binomial regression is:

$$\mu = \exp\left(\beta_0 + \sum \beta_i X_i\right)$$

Where μ is the mean and X_i are the characteristics that are used to predict the mean. In SAS program, PROC GENMOD was used to compute the parameters, which are the mean and variance of the negative binomial distribution. PROC GENMOD procedure fits generalized linear models is an extension of traditional linear model and therefore suitable to a wider range of data analysis problems. But traditional linear models are used extensively in statistical data analysis. The traditional linear models have the following limitations:

- Data cannot assume to be normally distributed
- The traditional linear model may not be valid, when the mean of the data is naturally limited to range of values
- Unrealistic to assume that variance of the data set is same for all observations.

A stepwise procedure was used to select the best variables to estimate. This is known to be forward selection stepwise procedure. The following steps are followed for building a model:

- In the first step, all the variables of site that were available were fit to the data individually. The variable that individually provides p- values lower than 0.05 was selected in the model.
- In the next step, taking ADT as a base variable, remaining variables were individually added to the model and the one with the lowest p- value is added to the model (i.e. p- value less than or equal to 0.05). The above

procedure is followed until desired set of variables are obtained with the p-values less than or equal to 0.05.

The following is an example of the general model in the forward selection process:

$$\textbf{Total= exp } (\mu\textbf{+Dy+lnADT+lnTRCKS+AC+Lns +lnRW+lnSW+MW+lnSL})$$

Where μ denotes the overall mean and Dy represents an offset value for the duration of the time period.

The variables that were considered in this study were: date of collection period, the duration of collection period, average daily traffic (ADT), the percentage of truck traffic (%TRCKS), the number of lanes (Lns), the road width (RW), the shoulder width (SW), the median width (MW) and four classification variables were used in this study:

- SYS_CL
- ACS
- FC

The descriptions of class variables are given below:

A) SYS_CL– System Classification

I - Interstate highway

M - Major road

A - Auxiliary road

L- Local, state road

B) ACS – Highway access type as journalized

N – No access control

L- Limited access control

F – Full access control

C) FC- Functional classification

01 – Rural Interstate

02 – Rural Principal Arterial

06 – Rural Minor Arterial

07 – Rural Major Collector

08 – Rural Minor Collector

09 – Rural Local

11 – Urban Interstate

12 – Urban Freeway and Expressway

14 – Urban Principal Arterial

16 – Urban Minor Arterial

17 – Urban Collector

19 – Urban Local

The collected data for control sites and treatment sties were formatted in excel sheet as per SAS program requirements and stored in the user data library. The data for treatment sties before construction was considered.

A general SAS program was used in this study, as follows:

```
Proc genmod; class typ treatment construction cnty MCL SYS_CL ACS FC AC;
Model total = SYS_CL ACS FC ADTh Trcks Ins RW SW / dist=nb link=log
Offset=Dy type3 Wald; REPEATED SUBJECT=TYP; run;
```

The variables with p-values less than or equal to 0.05 indicates the best fit for the model. The negative binomial means and variances were used for each treatment site to calculate the Empirical Bayes estimates for the mean crash count for that site in a specified time periods. The crash data during the construction period was not considered in the analysis.

The following steps were followed for model building and calculating the crash reduction factors (CRF's) for the improvement categories:

Step 1: Model Building

The regression coefficients β_0, β_1 β_2 ....and β_i and the dispersion parameter, φ, where estimated by using 'PROC GENMOD' of SAS.

Step 2: Forward Selection Process

- The five 'class' variables were used in model building procedure; they may have character or numeric values. The five class variables used in the study were MCL, SYS_CL, ACS, FC, and AC.
- All the variables like ADT, TRCKS, RW, SW, etc of site that was available were fit to the data individually. The variable that individually provides p- values lower than 0.05 was selected in the model.
- In the next step, taking ADT as base variable, remaining variables were individually added to the model and the one with the lowest p-value is added to the model (i.e. p- value less than or equal to 0.05). The above procedure is followed until desired set of variable are obtained with the p-values less than or equal to 0.05.
- The general model in the forward selection process was:

$$\textbf{Total} = \exp(\mu + Dy + \ln ADT + \ln TRCKS + Lns + \ln RW + \ln SW + MW + \ln SL)$$

Where μ denotes the overall mean and Dy represents to an offset value for the duration of the time period. Dy value corrects the offset for the time period immediately after the construction period if it is less than one full year.

Step 3: Calculation for Crash Reduction Factors

For an observed crash count (K), and the expected value for observed crashes (E (λ)), calculated from SAS program.

A. Calculation for EB estimate Crashes

An EB estimate of crashes is a weighted average of the observed crashes, K and the expected crashes, E (λ).

An EB Estimate, denoted as $\hat{\lambda}_{EB}$, is estimated using weight factor, α as follows:

$$\hat{\lambda}_{EB} = \alpha E(k) + (1-\alpha)K$$

Where,

$$\alpha = \frac{1}{1 + \frac{\mathrm{V}(k)}{\mathrm{E}(\lambda)}}$$

Var (λ) = variance of observed crash count.

The weight factor α can be estimated from the over-dispersion parameter and the expected crash rate for the treatment site:

$$\alpha = \frac{1}{1 + \phi\,\mathrm{E}(\lambda)}$$

Where,

ϕ = Over dispersion parameter

The variance of $\hat{\lambda}_{EB}$ is then determined as:

$$V(\hat{\lambda}_{EB}) = (1-\alpha)\hat{\lambda}_{EB}$$

B. Calculation for the expected value of crash count that would have occurred during after period, if the improvement had not been made.

Adjustment factor, C_y

$$C_y = \frac{\hat{\lambda}_y}{\hat{\lambda}_b}$$

Where,

$\hat{\lambda}_y$ = The mean crash rate of the treatment site in year y

$\hat{\lambda}_b$ = The mean crash rate in a base year

The expected crash rate during before period, $\hat{\lambda}_b$

$$\hat{\lambda}_b = \frac{\sum_{before} \lambda_{EB,y}}{\sum_{before} Cy},$$

$$\text{and } V(\hat{\lambda}_b) = \frac{\sum V(\lambda_{EB,y})}{(\sum_{before} C_y)^2}$$

The expected crash rates for a treatment site during after period, $\hat{\lambda}_A$

$$\hat{\lambda}_A = C_A * \hat{\lambda}_b,$$

$$\text{and } V(\lambda_A) = C_A{}^2 * (\hat{\lambda}_b)$$

C. Calculation for crash reduction factors

The effectiveness of the treatment, $\hat{\theta}$

$$\hat{\theta} = \frac{\sum_{after} \hat{K}_A}{\sum_{after} \hat{\lambda}_A}$$

$$\text{Bias, } \hat{b} = 1 + \frac{\sum_{After} V(\hat{\lambda}_A)}{\sum_{After} (\hat{\lambda}_A)^2}$$

The unbiased estimate of $\hat{\theta}$, $\hat{\theta}_u$

$$\hat{\theta}_u = \frac{\hat{\theta}}{\hat{b}} = \frac{\sum_{\text{After}} \hat{K}_A \Big/ \sum_{\text{After}} \hat{\lambda}_A}{1 + \dfrac{\sum_{\text{After}} V(\hat{\lambda}_A)}{\sum_{\text{After}} (\hat{\lambda}_A)^2}},$$

$$\text{and Variance} = V(\hat{\theta}_u) = (\hat{\theta}_u)^2 = \left(\frac{\hat{\theta}}{\hat{b}}\right)^2 \left(\frac{1}{\sum_{\text{After}} K_A} + \frac{\sum_{\text{After}} V(\hat{\lambda}_A)}{(\sum_{\text{After}} \hat{\lambda}_A)^2} \right)$$

Crash Reduction Factor, CRF

$$CRF = 100 * \left(1 - \hat{\theta}_u\right)$$

The standard error of an estimate is the square root of its variance and the standard error of the estimated CRF is 100 times the standard error of $\hat{\theta}$.

CHAPTER 4

Data Collection

4.1 Introduction to Data Collection

Crash counts for the before/after period for a treatment and comparison sites were collected. Most of the suggested improvements were carried out in the mid 90's. At least two years of crash data before improvement and two years of crash data after an improvement were considered for the analysis. Data related to the physical characteristics of roadway segments and crash counts were provided by ODOT.

4.2 Data for Treatment and Control Sites

A treatment site is a place where an improvement was physically introduced to reduce the crashes and thus improve the safety of the location. For analysis, the treatment group in each improvement type contained a number of treatment sites.

1. Relocate/Remove Fixed Object
2. Install Median Barrier

Comparison sites are sites more or less similar to treatment sites characteristics. In before-after studies, the comparison sites data is essential component in the analysis. Comparison data sites will help to adjust for the other confounding effects which could affect the crashes from the before to after period. To eliminate RTM effects; such an adjustment is needed because there is a time trend in occurrence of crashes (i.e. crashes rate is increasing overtime). Comparison group data also adjusts for differences in road geometry, traffic volume, weather etc. the treatment and comparison sites, which are used for analysis, are showed in appendix A.

Crash Counts

The crash data for at least 2 years before and after are collected for both treatment and comparison sites. The duration should be long enough to allow for reasonably large crash counts yet not so long that other non-treatment related factors might influence the analysis.

Exposure Measures

The site's exposures such as traffic volumes, section length, number of lanes, duration of time etc. are collected for treatment and control sites.

ODOT office of the Technical Services published seven different Roadway

Inventory Reports for the development and maintenance of a Linear Referencing System (LRS) for state, county, township, and municipal road and street systems:

- State System Basic Road Inventory (RI-06)
- Listing of Local Roads-sorted by county (RI-34A)

- NHS and PAS Mileage by functional class(RI-339)
- Listing of Local Roads sorted by Township(RI34B)
- Centerline Miles, Lane Miles, and Vehicle Miles Traveled Report (State Highway System only) (RI-82B)
- State Highway System Lane Miles (RI-367)
- Roadway Description Inventory Report (DESTAPE)-sorted by county and district.

State System Basic Road Inventory (RI-06) describes characteristics like surface type, surface width, roadway width, system classification, median width, and highway access type, number of driving lanes, functional classification and urban area code of the specified road segment. DESTAPE helps to establish the treatment and comparison site locations by route type and log points. Difference between begin log and end log gives the length of roadway segment. Using annual reports on highway safety evaluation and interaction with districts, the treated road segment was located.

The crash data for comparison sites were supplied by ODOT central office. This data was later organized by before and after periods of improvements.

The date of the start and the date of the completion of the work for any treatment site denoted the period of the construction. The month in which construction began and ended were considered whole months for the treatment period. For example, for the work that was begun on August 05, 1997 and ended on September 16, 1997, the construction period was from

August 1997 to September 1997. Crashes that occurred during the construction period were not considered.

Crashes are used to identify safety problems of a particular site. It is also used to identify the crash pattern at a site, from which possible cause of a crash is identified.

For the analysis, crashes are classified by type of crashes and severity of crashes, as follows:

Type of crashes: rear-end, angle, left-turn, head-on, fixed object, sideswipes, and other.

Severity of crashes: Injury/fatal (I/F) and property damage only (PDO) crashes.

CHAPTER 5

STATISTICAL MODELING

5.1 Remove/Relocate Fixed Object

The model selected at the end of the forward selection process was:

Total = exp (Dy + FC + LnADT + SW + ACS + LnTRCKS),

And I/F Total = exp (Dy + FC+ LnADT+ SW + ACS)

Where,

Total = Total crashes

I/F Total = Injury/Fatal crashes

FC = Functional class

ACS = Highway access type journalized

LnTRCKS = Percentage of trucks

LnADT = Average daily traffic

SW = Shoulder width

Table 6 and 7 show the Wald statistics for the best model for both total and Injury/Fatal crashes for Relocate/Remove fixed object.

Table 6: Wald Statistics for the Best Model for Total Crashes for Remove/Relocate Fixed Object

Source	DF	Chi-square	Pr > Chisq
FC	4	124.37	0.0001
LnADT	1	1.33	0.2489
LNSW	1	12.61	0.0004
ACS	1	95.27	0.0001
LNTRCKS	1	4.62	0.0317

Table 7: Wald Statistics for The Best Model for I/F Crashes for Remove/Relocate Fixed Object

Source	DF	Chi-square	Pr > Chisq
FC	4	84.45	0.0001
LnADT	1	5.75	0.0165
LNSW	1	17.19	0.0001
ACS	1	23.68	0.0001

After the best model was selected in the forward selection process, SAS program was used to create expected crash count for each treatment site for the before and after period of construction. These expected crash counts, which were the means of Negative Binomial (NB) distribution, were used to calculate the Empirical Bayes (EB) estimate of the crashes of a treatment site. The EB estimates were further used to calculate the CRF for the total crashes and I/F. the comprehensive details of adjusted EB total and averages are given in appendix B.

The estimated CRF for all crashes after installing barrier is 38.23% with a standard error estimate of ±10.30%. The estimated CRF for I/F crashes is 38.13% with a standard error estimate of ±13.40 %. For both cases, there is a statistically reduction in crashes based on the data available in this study.

5.2 Install Median Barrier

The model selected at the end of the forward selection process was:

Total = exp (Dy + LnADT), and

I/F Total = exp (Dy + LnADT+ MIDPOINT)

Where,

Total = Total crashes

I/F Total = Injury/Fatal crashes

LnADT = Average daily traffic

Table 8 and 9 show the Wald statistics for the best model for both total and Injury/Fatal crashes for Install Median Barrier.

Table 8: Wald Statistics for the Best Model for Total Crashes for Install Median Barrier

Source	DF	Chi-square	Pr > Chisq
LnADT	1	11.04	0.0009

Table 9: Wald Statistics for The Best Model for I/F Crashes for Install Median Barrier

Source	DF	Chi-square	Pr > Chisq
LnADT	1	8.59	0.0034
Midpoint	1	6.30	0.0121

After the best model was selected in the forward selection process, SAS program was used to create expected crash count for each treatment site for the before and after period of construction. These expected crash counts, which were the means of NB distribution, were used to calculate the empirical base (EB) estimate of the crashes of a treatment site. The EB estimates were further used to calculate the CRF for the total crashes and Injury/Fatal (I/F) crashes. The comprehensive details of adjusted EB total and averages are given in appendix B.

The estimated CRF for total crashes after Installing Median Barrier is 86.33 percent with a standard error estimate of ±2.92 percent. The estimated CRF for injury / fatality accidents is 88.37 percent with a standard error estimate of ±5.23 percent. For both cases, there is a statistically significant reduction in crashes based on the data available in this study.

An excel sheet containing adjusted EB total and averages are showed in appendix B and also SAS output files are showed in appendix B.

CHAPTER 6

Conclusion

6.1 Conclusion

This thesis developed CRFs for two improvement categories: Remove/Relocate Fixed Object, and Install Median Barrier. An Empirical Baye's (EB) methodology was implemented in developing CRF's for all crashes and injury/fatality crashes. By using EB method, the 'Regression-to-the-Mean' bias was addressed.

In this study, four treatment sites and forty comparison sites were used in both improvement categories. The following crash reduction factors were developed for the two improvement categories:

1. Remove/Relocate Fixed Object
    - All crashes: 39.13 percent decrease in crashes with a standard error estimate of ±10.16 percent
    - Injury and Fatality Crashes: 39.55 percent decrease in crashes with a standard error estimate of ±13.10 percent

This shows a reduction in crashes due to the above improvement.

2. Install Median Barrier

- All crashes: 86.34 percent decrease in crashes with a standard error estimate of ±2.92 percent
- Injury and Fatality Crashes: 88.37 percent decrease in crashes with a standard error estimate of ±5.23 percent

This shows a significant reduction in crashes due to the above improvement.

For Remove/Relocate Fixed Object, the CRF estimates are somewhat consistent with the other studies, whereas for Install Median Barrier, it varied significantly. This study was limited in terms of the number of treatment and comparison sites because of the available data at the time of the research. By adding more treatment and comparison sites, the estimates for CRF's could be more precise.

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APPENDIX A – Treatment and Control Sites

Treatment Sites

S.no.	Improvement Category	District	County	Route	Date of Start	Date of Completion
1	REMOVE/RELOCATE FIXED OBJECT	9	PIK	335R	1/12/1998	1/31/1998
		8	CLE	132R	3/1/1999	6/21/1999
		9	BRO	68R	5/6/1996	8/3/1998
		7	CHP	560R	8/1/2001	8/31/2001
2	INSTALL MEDIAN BARRIER	6	FRA	270R	10/1/1997	4/30/2000
		6	FRA	270R	8/1/1998	12/31/2001
		6	DEL	71R	2/1/2000	5/31/2002
		6	FRA	71R	2/1/2000	5/31/2002

Control Sites

Improvement Category	District	County	Route
	9	PIK	335R
	9	PIK	335R
	9	PIK	335R
	9	PIK	335R
	9	PIK	335R
	9	PIK	335R
	9	ADA	781R
	8	BUT	122R
	8	BUT	122R
	8	BUT	122R
	8	CLE	48R
	8	CLE	48R
	8	CLE	50R
	8	CLE	50R
	8	CLE	132R
	8	CLE	132R
	8	CLE	132R
	8	CLE	132R
	8	CLE	132R
	8	CLE	132R
	9	BRO	125R

	8	WAR	73R
	8	WAR	73R
	8	WAR	73R
	8	WAR	73R
	8	BUT	27R
	8	BUT	27R
	8	HAM	747R
	7	MOT	40R
	8	BUT	127R
	7	CHP	560R
	7	CHP	560R
	7	CHP	560R
	7	CHP	187R
	7	CHP	187R
	7	CHP	560R
	7	CHP	245R
	7	CHP	54R
	7	CLA	54R
	7	CLA	54R

Control Sites

Improvement Category	District	County	Route
INSTALL MEDIAN BARRIER	6	FRA	270R
	6	FRA	315R
	6	FRA	315R
	6	FRA	315R
	6	FRA	670R
	12	CUY	2R
	12	CUY	71R
	12	CUY	71R
	12	CUY	71R
	12	CUY	71R
	12	CUY	71R
	12	CUY	71R
	12	CUY	71R
	12	CUY	71R
	12	CUY	71R
	12	CUY	71R
	12	CUY	71R
	12	CUY	71R
	12	CUY	90R
	12	CUY	90R
	12	CUY	2R

	12	CUY	71R
	12	CUY	71R
	12	CUY	71R
	12	CUY	71R
	12	CUY	90R
	12	CUY	90R
	12	CUY	90R
	12	CUY	90R
	12	CUY	90R
	6	FRA	71R
	6	FRA	71R
	4	SUM	76R
	4	SUM	76R
	4	SUM	76R
	8	HAM	71R
	8	HAM	71R
	8	HAM	71R
	8	HAM	71R
	8	HAM	71R

Appendix B

Remove/Relocate Fixed object – ALL CRASHES

FORWARD SELECTION PROCESS (looking for smallest p-value < 0.05)

Step1 – Evaluate each variable by itself:

- MIDPOINT P-value: 0.2502
- TG P-value: 0.4320
- LNADT P-value: 0.0096
- LNSL P-value: 0.0046
- MCL P-value: 0.0719
- SYS_CL P-value: 0.0001
- ACS P-value: 0.6901
- FC P-value: 0.0001
- LNTRCKS P-value: 0.7327
- LNS P-value: NONE
- LNRW P-value: 0.4328
- LNSW P-value: 0.4458
- MW P-value: NONE

Variable FC has the lowest p-value; carry it to step 2. Remove LNS, and MW from consideration.

Step2 – Evaluate each remaining variable with FC:

- FC (P-value: 0.0001), TG (P-value: 0.0007)
- FC (P-value: 0.0623), LNADT (P-value: 0.0001)
- FC (P-value: 0.0079), LNSL (P-value: 0.0010)
- FC (P-value: 0.0001), MCL (P-value: 0.0001)
- FC (P-value: 0.0496), SYS_CL (P-value: 0.0044)
- FC (P-value: 0.0001), ACS (P-value: 0.0001)
- FC (P-value: 0.0001), LNTRCKS (P-value: 0.0001)
- FC (P-value: 0.0001), LNRW (P-value: 0.0001)
- FC (P-value: 0.0001), LNSW (P-value: 0.0001)

Variable FC & LNADT has the lowest p-value; carry it to step 3

Step3 – Evaluate each remaining variable with LNADT & FC

- FC (P-value: 0.0092), LNADT (P-value: 0.0001), TG (P-value: 0.0138)
- FC (P-value: 0.4852), LNADT (P-value: 0.0018), LNSL (P-value: 0.0156)
- FC (P-value: 0.0002), LNADT (P-value: 0.0001), MCL (P-value: 0.0001)
- FC (P-value: 0.2197), LNADT (P-value: 0.0001), SYS_CL (P-value: 0.1160)
- FC (P-value: 0.0001), LNADT (P-value: 0.0001), ACS (P-value: 0.0001)

- FC (P-value: 0.0047), LNADT (P-value: 0.0870), LNTRCKS (P-value: 0.0001)
- FC (P-value: 0.0001), LNADT (P-value: 0.0006), LNRW (P-value: 0.0004)
- FC (P-value: 0.0001), LNADT (P-value: 0.0243), LNSW (P-value: 0.0001)

Variable FC, LNADT & LNSW has the lowest p-value; carry it to step 4

Step4: Evaluate each remaining variable with LNADT, FC & LNSW

- FC P-value: 0.0001,LNADT P-value: 0.1891,LNSW P-value: 0.0001,TG P-value: 0.3135
- FC P-value: 0.0260,LNADT P-value: 0.0605,LNSW P-value: 0.0044, LNSL P-value: 0.9969
- FC P-value: 0.0001,LNADT P-value: 0.0995,LNSW P-value: 0.0043,MCL P-value: 0.3290
- FC P-value: 0.0001,LNADT P-value: 0.0297,LNSW P-value: 0.0003, SYS_CL P-value: 0.3785
- FC P-value:0. 0001,LNADT P-value:0. 0182,LNSW P-value: 0. 0001,ACS P-value: 0.0001
- FC P-value: 0.0001,LNADT P-value: 0.3000,LNSW P-value: 0.0003 LNTRCKS P-value: 0.0269
- FC P-value: 0.0001,LNADT P-value: 0.3311,LNSW P-value: 0.4916, LNRW P-value: 0.9172

Variable FC, LNADT, ACS & LNSW has the lowest p-value; carry it to step 5

Step5: Evaluate each remaining variable with LNADT, FC, ACS & LNSW

- FC P-value: 0.0001, LNADT P-value: 0.0219, LNSW P-value:0.0001 ACS P-value: 0.0001, TG P-value: 0.0332.
- FC P-value: 0.0001, LNADT P-value: 0.0022, LNSW P-value:0.0559, ACS P-value: 0.0001, LNSL P-value: 0.5971.
- FC P-value: 0.0001, LNADT P-value: 0.0024, LNSW P-value: 0.1390, ACS P-value: 0.0001, MCL P-value: 0.0236.
- FC P-value: 0.0001, LNADT P-value: 0.0024, LNSW P-value: 0.0013, ACS P-value: 0.0204, SYS_CL P-value: 0.4399.
- FC P-value: 0.0001, LNADT P-value: 0.2489, LNSW P-value: 0.0004, ACS P-value: 0.0001, LNTRCKS 0.0317.

- FC P-value: 0.0001, LNADT P-value: 0.2720, LNSW P-value:0.1460, ACS P-value: 0.0001, LNRW P-value: 0.4493.

Variable FC, LNADT, ACS, LNTRCKS & LNSW has the lowest p-value; carry it to step 6

Step6: Evaluate each remaining variable with LNADT, FC, ACS, LNTRCKS, & LNSW

- FC P-value: 0.0001, LNADT P-value: 0.0429, LNSW P-value: 0.1577,
  ACS P-value: 0.0001, LNTRCKS P-value: 0.0193,
  LNSL P-value: 0.3830.
- FC P-value: 0.0001, LNADT P-value: 0.0793, LNSW P-value: 0.0001,
  ACS P-value: 0.0001, LNTRCKS P-value: 0.0284,
  TG P-value: 0.1203.
- FC P-value: 0.0001, LNADT P-value: 0.0559, LNSW P-value: 0.1546,
  ACS P-value: 0.0001, LNTRCKS P-value: 0.0468,
  MCL P-value: 0.1153.
- FC P-value: 0.0001, LNADT P-value: 0.2383, LNSW P-value: 0.0801,
  ACS P-value: 0.0780, LNTRCKS P-value: 0.1074,
  SYS_CL P-value: 0.1436.
- FC P-value: 0.0001, LNADT P-value: 0.5451, LNSW P-value: 0.0196,
  ACS P-value: 0.0001, LNTRCKS P-value: 0.0049,
  LNRW P-value: 0.1180.

Therefore, the model containing the LNADT, FC, ACS, LNTRCKS, & LNSW variables found in step 5 is the most significant statistical combination.

Remove/Relocate fixed object – I/F CRASHES

FORWARD SELECTION PROCESS (looking for smallest p-value < 0.05)

Step1 – Evaluate each variable by itself:

- MIDPOINT P-value: 0.7573
- TG P-value: 0.7373
- LNADT P-value: 0.0001
- LNSL P-value: 0.0156
- MCL P-value: 0.0001
- SYS_CL P-value: 0.0001
- ACS P-value: 0.9204
- FC P-value: 0.0001
- LNTRCKS P-value: 0.2431
- LNS P-value: NONE
- LNRW P-value: 0.9346
- LNSW P-value: 0.6941
- MW P-value: NONE

Variable LNADT has the lowest p-value; carry it to step 2. Remove LNS, and MW from consideration.

Step2 – Evaluate each remaining variable with LNADT:

- LNADT P-value: 0.0001, TG P-value: 0.0016
- LNADT P-value: 0.0001, FC P-value: 0.1670
- LNADT P-value: 0.0003, LNSL P-value: 0.0024
- LNADT P-value: 0.0001, MCL P-value: 0.0001
- LNADT P-value: 0.0001, SYS_CL P-value: 0.0115
- LNADT P-value: 0.0001, ACS P-value: 0.7991
- LNADT P-value: 0.0001, LNTRCKS P-value: 0.0381
- LNADT P-value: 0.0001, LNRW P-value: 0.0205
- LNADT P-value: 0.0001, LNSW P-value: 0.0047

Variable LNSW & LNADT has the lowest p-value; carry it to step 3

Step3 – Evaluate each remaining variable with LNADT & LNSW:

- LNADT P-value: 0.0001, LNSW P-value: 0.0397, TG P-value: 0.0010
- LNADT P-value: 0.0001, LNSW P-value: 0.5996, LNSL P-value: 0.0021.
- LNADT P-value: 0.0001, LNSW P-value: 0.4016, SYS_CL P-value: 0.0163.
- LNADT P-value: 0.0001, LNSW P-value: 0.0001, ACS P-value: 0.5894.
- LNADT P-value: 0.0001, LNSW P-value: 0.0001, FC P-value: 0.0001.
- LNADT P-value: 0.0001, LNSW P-value: 0.0001, LNTRCKS P-value: 0.0711.

- LNADT P-value: 0.0001, LNSW P-value: 0.0024, LNRW P-value: 0.0244.
- LNADT P-value: 0.0001, LNSW P-value: 0.0034, MCL P-value: 0.0109.

Variable FC, LNADT & LNSW has the lowest p-value; carry it to step 4

Step4: Evaluate each remaining variable with LNADT, FC & LNSW

- LNADT P-value: 0.0001, LNSW P-value: 0.0001, FC P-value: 0.0001, TG P-value: 0.0617.
- LNADT P-value: 0.0002, LNSW P-value: 0.0001, FC P-value: 0.0942, LNSL P-value: 0.0631.
- LNADT P-value: 0.0001, LNSW P-value: 0.0001, FC P-value: 0.0011, SYS_CL P-value: 0.1780.
- LNADT P-value: 0.0165, LNSW P-value: 0.0001, FC P-value: 0.0001, ACS P-value: 0.0001.
- LNADT P-value: 0.0064, LNSW P-value: 0.0001, FC P-value: 0.0001, LNTRCKS P-value: 0.0134.
- LNADT P-value: 0.0001, LNSW P-value: 0.3796, FC P-value: 0.0001, LNRW P-value: 0.0298.
- LNADT P-value: 0.0370, LNSW P-value: 0.7419, FC P-value: 0.0001, MCL P-value: 0.0096.

Variable FC, LNADT, ACS & LNSW has the lowest p-value; carry it to step 5

Step5: Evaluate each remaining variable with LNADT, FC, ACS, & LNSW

- LNADT P-value: 0.0001, LNSW P-value: 0.0001, FC P-value: 0.0001 ACS P-value: 0.0001, TG P-value: 0.0626.
- LNADT P-value: 0.0002, LNSW P-value: 0.0001, FC P-value: 0.0007 ACS P-value: 0.0001, LNSL P-value: 0.0706.
- LNADT P-value: 0.0001, LNSW P-value: 0.0001, FC P-value: 0.0001 ACS P-value: 0.0213, SYS_CL P-value: 0.1736.
- LNADT P-value: 0.0050, LNSW P-value: 0.0001, FC P-value: 0.0001 ACS P-value: 0.0001, LNTRCKS P-value: 0.0176.
- LNADT P-value: 0.0001, LNSW P-value: 0.3480, FC P-value: 0.0001 ACS P-value: 0.0001, LNRW P-value: 0.0308.
- LNADT P-value: 0.0288, LNSW P-value: 0.7220, FC P-value: 0.0001 ACS P-value: 0.0001, MCL P-value: 0.0109.

Therefore, the model containing the LNADT, FC, ACS, & LNSW variables found in step 5 is the most significant statistical combination.

Install Median Barrier– ALL CRASHES

FORWARD SELECTION PROCESS (looking for smallest p-value < 0.05)

Step1 – Evaluate each variable by itself:

- LnADT P-value: 0.0001
- Sys_cl P-value: 0.0229 (not applicable)
- Acs P-value: 0.0001 (not applicable)
- Fc P-value: 0.0229 (not applicable)
- Lntrcks P-value: 0.1514
- Lns P-value: No value
- Lnrw P-value: No value
- Lnsw P-value: No value
- Mw P-value: 0.7905
- Ac P-value: 0.6218 (not applicable)
- Lnsl P-value: 0.2149
- Midpoint P-value: 0.1892
- Tg P-value: 0.3400

Variable LnADT has the lowest p-value; carry it to step 2. Remove Lns, Lnrw, Lnsw, Sys_cl, Acs, Ac and Fc from consideration.

Step2 – Evaluate each remaining variable with LnADT:

- LnADT P-value: 0.0001, Lntrcks P-value: 0.2377.
- LnADT P-value: 0.0001, Mw P-value: 0.8797.
- LnADT P-value: 0.0001, Midpoint P-value: 0.0565.
- LnADT P-value: 0.0008, Tg P-value: 0.7649.
- LNADT P-value: 0.0004, Lnsl P-value: 0.4913.

Therefore, the model containing the LNADT variables found in step 1 is the most significant statistically.

Install Median Barrier– I/F CRASHES

FORWARD SELECTION PROCESS (looking for smallest p-value < 0.05)

Step1 – Evaluate each variable by itself:

- Tg P-value: 03844
- LnSL P-value: 0.2909
- Acs P-value: 0.0001 (not applicable)
- Ac P-value: 0.6282 (not applicable)

- LnTrcks P-value: 0.0636
- Lns P-value: No value
- Lnrw P-value: No value
- Mw P-value: 0.8703
- Fc P-value: 0.0130 (not applicable)
- Sys_cl P-value: 0.0130 (not applicable)
- Lnsw P-value: No value
- LnADT P-value: 0.0010
- Midpoint P-value: 0.0006

Variable LnADT has the lowest p-value; carry it to step 2. Remove Lns, Lnrw, Lnsw, Sys_cl, Acs, Ac and Fc from consideration.

Step2 – Evaluate each remaining variable with LnADT:

- LnADT P-value: 0.0020, LnSL P-value: 0.5343.
- LnADT P-value: 0.0005, Lntrcks P-value: 0.1423.
- LnADT P-value: 0.0009, Mw P-value: 0.9390.
- LnADT P-value: 0.0024, Tg P-value: 0.6787.
- LnADT P-value: 0.0007, Midpoint P-value: 0.0002.

Variable Midpoint & LNADT has the lowest p-value; carry it to step 3

Step3 – Evaluate each remaining variable with LNADT & Midpoint:

- LnSL P-value: 0.9379 LnADT P-value: 0.0004
  Midpoint P-value: 0.0001
- Lntrcks P-value: 0.2272 LnADT P-value: 0.0005
  Midpoint P-value: 0.0001
- Mw P-value: 0.6838 LnADT P-value: 0.0002
  Midpoint P-value: 0.0001
- Tg P-value: 0.7602 LnADT P-value: 0.0036
  Midpoint P-value: 0.0001

Therefore, the model containing the LNADT & Midpoint variables found in step 2 is the most significant statistical combination.

Relocate/Remove Fixed Object for All Crashes

```
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                                      The GENMOD Procedure

                                       Model Information

              Data Set                         WORK.DATA1
              Distribution              Negative Binomial
              Link Function                           Log
              Dependent Variable                    Total    Total
              Offset Variable                          DY    DY
              Observations Used                       262

                                    Class Level Information

          Class              Levels    Values

          TYP                    44    C1-1 C1-10 C1-2 C1-3 C1-4 C1-5 C1-6 C1-7 C1-8
C1-9
                                       C2-1 C2-10 C2-2 C2-3 C2-4 C2-5 C2-6 C2-7 C2-8
C2-9
                                       C3-1 C3-10 C3-2 C3-3 C3-4 C3-5 C3-6 C3-7 C3-8
C3-9
                                       C4-1 C4-10 C4-2 C4-3 C4-4 C4-5 C4-6 C4-7 C4-8
C4-9
                                       T1-1 T2-1 T3-1 T4-1
          Treatment               2    C T
          Construction            1    N
          CNTY                   10    ADA(9) BRO(9) BUT(8) CHP(7) CLA(7) CLE(8) HAM(8)
                                       MOT(7) PIK(9) WAR(8)
          MCL                     3    1 2 4
          SYS_CL                  3    A L M
          ACS                     2    L N
          FC                      5    6 7 8 14 16

                                     Parameter Information

                            Parameter       Effect       ACS    FC

                            Prm1            Intercept
                            Prm2            FC                  6
                            Prm3            FC                  7
                            Prm4            FC                  8
                            Prm5            FC                  14
                            Prm6            FC                  16
                            Prm7            lnADT
                            Prm8            lnSW
                            Prm9            ACS          L
                            Prm10           ACS          N
                            Prm11           lnTrcks
```

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                                      The GENMOD Procedure

                            Criteria For Assessing Goodness Of Fit

                 Criterion                 DF           Value        Value/DF

                 Deviance                 253        275.9814          1.0908
                 Scaled Deviance          253        275.9814          1.0908
                 Pearson Chi-Square       253        276.7846          1.0940
                 Scaled Pearson X2        253        276.7846          1.0940
                 Log Likelihood                      462.2745

         Algorithm converged.
```

Analysis Of Initial Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept		1	1.4827	0.9875	-0.4527	3.4181	2.25	0.1332
FC	6	1	2.1956	0.4342	1.3445	3.0467	25.57	<.0001
FC	7	1	-0.2449	0.1685	-0.5751	0.0853	2.11	0.1461
FC	8	1	-1.3426	0.4192	-2.1642	-0.5210	10.26	0.0014
FC	14	1	0.5334	0.2471	0.0491	1.0177	4.66	0.0309
FC	16	0	0.0000	0.0000	0.0000	0.0000	.	.
lnADT		1	0.1995	0.1024	-0.0012	0.4001	3.80	0.0513
lnSW		1	-1.1324	0.1516	-1.4296	-0.8352	55.78	<.0001
ACS	L	1	-0.6847	0.3766	-1.4227	0.0534	3.31	0.0690
ACS	N	0	0.0000	0.0000	0.0000	0.0000	.	.
lnTrcks		1	-0.4754	0.1665	-0.8018	-0.1491	8.15	0.0043
Dispersion		1	0.2597	0.0573	0.1686	0.4001		

NOTE: The negative binomial dispersion parameter was estimated by maximum likelihood.

GEE Model Information

Correlation Structure	Independent
Subject Effect	TYP (44 levels)
Number of Clusters	44
Correlation Matrix Dimension	8
Maximum Cluster Size	8
Minimum Cluster Size	3

Algorithm converged.

The GENMOD Procedure

Analysis Of GEE Parameter Estimates
Empirical Standard Error Estimates

Parameter		Estimate	Standard Error	95% Confidence Limits		Z	Pr > |Z|
Intercept		1.4827	1.5536	-1.5623	4.5277	0.95	0.3399
FC	6	2.1956	0.3384	1.5323	2.8589	6.49	<.0001
FC	7	-0.2449	0.3338	-0.8992	0.4093	-0.73	0.4631
FC	8	-1.3426	0.6818	-2.6790	-0.0062	-1.97	0.0489
FC	14	0.5334	0.4462	-0.3411	1.4079	1.20	0.2319
FC	16	0.0000	0.0000	0.0000	0.0000	.	.
lnADT		0.1995	0.1730	-0.1396	0.5386	1.15	0.2489
lnSW		-1.1324	0.3188	-1.7573	-0.5075	-3.55	0.0004
ACS	L	-0.6847	0.0701	-0.8222	-0.5472	-9.76	<.0001
ACS	N	0.0000	0.0000	0.0000	0.0000	.	.
lnTrcks		-0.4754	0.2213	-0.9091	-0.0418	-2.15	0.0317

Wald Statistics For Type 3 GEE Analysis

Source	DF	Chi-Square	Pr > ChiSq
FC	4	124.37	<.0001
lnADT	1	1.33	0.2489
lnSW	1	12.61	0.0004
ACS	1	95.27	<.0001
lnTrcks	1	4.62	0.0317

The GENMOD Procedure

Model Information

Data Set	WORK.DATA1	
Distribution	Negative Binomial	
Link Function	Log	
Dependent Variable	Total	Total
Offset Variable	DY	DY
Observations Used	262	

Class Level Information

Class	Levels	Values
TYP	44	C1-1 C1-10 C1-2 C1-3 C1-4 C1-5 C1-6 C1-7 C1-8 C1-9 C2-1 C2-10 C2-2 C2-3 C2-4 C2-5 C2-6 C2-7 C2-8 C2-9 C3-1 C3-10 C3-2 C3-3 C3-4 C3-5 C3-6 C3-7 C3-8 C3-9 C4-1 C4-10 C4-2 C4-3 C4-4 C4-5 C4-6 C4-7 C4-8 C4-9 T1-1 T2-1 T3-1 T4-1
Treatment	2	C T
Construction	1	N
CNTY	10	ADA(9) BRO(9) BUT(8) CHP(7) CLA(7) CLE(8) HAM(8) MOT(7) PIK(9) WAR(8)
MCL	3	1 2 4
SYS_CL	3	A L M
ACS	2	L N
FC	5	6 7 8 14 16

Parameter Information

Parameter	Effect	ACS	FC
Prm1	Intercept		
Prm2	FC		6
Prm3	FC		7
Prm4	FC		8
Prm5	FC		14
Prm6	FC		16
Prm7	lnADT		
Prm8	lnSW		
Prm9	ACS	L	
Prm10	ACS	N	

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	254	274.4632	1.0806
Scaled Deviance	254	274.4632	1.0806

The GENMOD Procedure

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Pearson Chi-Square	254	308.1935	1.2134
Scaled Pearson X2	254	308.1935	1.2134

Log Likelihood 31.1682

Algorithm converged.

Analysis Of Initial Parameter Estimates

Parameter		DF	Estimate	Standard Error	Wald 95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept		1	-1.1020	0.9256	-2.9160	0.7121	1.42	0.2338
FC	6	1	2.2433	0.4485	1.3643	3.1223	25.02	<.0001
FC	7	1	-0.1002	0.1872	-0.4671	0.2667	0.29	0.5925
FC	8	1	-0.8018	0.4822	-1.7468	0.1432	2.77	0.0963
FC	14	1	0.4796	0.2607	-0.0313	0.9905	3.38	0.0658
FC	16	0	0.0000	0.0000	0.0000	0.0000	.	.
lnADT		1	0.4051	0.1003	0.2085	0.6017	16.31	<.0001
lnSW		1	-1.4265	0.1721	-1.7638	-1.0891	68.67	<.0001
ACS	L	1	-0.6406	0.3803	-1.3859	0.1047	2.84	0.0921
ACS	N	0	0.0000	0.0000	0.0000	0.0000	.	.
Dispersion		1	0.1908	0.0653	0.0975	0.3731		

NOTE: The negative binomial dispersion parameter was estimated by maximum likelihood.

GEE Model Information

Correlation Structure	Independent
Subject Effect	TYP (44 levels)
Number of Clusters	44
Correlation Matrix Dimension	8
Maximum Cluster Size	8
Minimum Cluster Size	3

Algorithm converged.

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The GENMOD Procedure

Analysis Of GEE Parameter Estimates
Empirical Standard Error Estimates

Parameter		Estimate	Standard Error	95% Confidence Limits		Z	Pr > |Z|
Intercept		-1.1020	1.3856	-3.8176	1.6137	-0.80	0.4264
FC	6	2.2433	0.5217	1.2208	3.2658	4.30	<.0001
FC	7	-0.1002	0.4256	-0.9344	0.7340	-0.24	0.8139
FC	8	-0.8018	0.7185	-2.2100	0.6064	-1.12	0.2644
FC	14	0.4796	0.5198	-0.5392	1.4983	0.92	0.3562
FC	16	0.0000	0.0000	0.0000	0.0000	.	.
lnADT		0.4051	0.1689	0.0741	0.7361	2.40	0.0165
lnSW		-1.4265	0.3440	-2.1008	-0.7521	-4.15	<.0001
ACS	L	-0.6406	0.1316	-0.8986	-0.3825	-4.87	<.0001
ACS	N	0.0000	0.0000	0.0000	0.0000	.	.

Wald Statistics For Type 3 GEE Analysis

Source	DF	Chi-Square	Pr > ChiSq
FC	4	85.45	<.0001
lnADT	1	5.75	0.0165
lnSW	1	17.19	<.0001

ACS	1	23.68	<.0001

Install Median Barrier for All Crashes

The GENMOD Procedure

Model Information

Data Set	WORK.DATA27	
Distribution	Negative Binomial	
Link Function	Log	
Dependent Variable	Total	Total
Offset Variable	DY	DY
Observations Used	292	

Class Level Information

Class	Levels	Values
TYP	44	C1-1 C1-10 C1-2 C1-3 C1-4 C1-5 C1-6 C1-7 C1-8 C1-9 C2-1 C2-10 C2-2 C2-3 C2-4 C2-5 C2-6 C2-7 C2-8 C2-9 C3-1 C3-10 C3-2 C3-3 C3-4 C3-5 C3-6 C3-7 C3-8 C3-9 C4-1 C4-10 C4-2 C4-3 C4-4 C4-5 C4-6 C4-7 C4-8 C4-9 T1-1 T2-1 T3-1 T4-1
Treatment	2	C T
Construction	1	N
CNTY	5	CUY(12) DEL(6) FRA(6) HAM(8) SUM(4)
MCL	1	2
SYS_CL	2	I M
ACS	2	F L
FC	2	11 12

Parameter Information

Parameter	Effect
Prm1	Intercept
Prm2	lnADT

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	290	341.3373	1.1770
Scaled Deviance	290	341.3373	1.1770
Pearson Chi-Square	290	324.1794	1.1179
Scaled Pearson X2	290	324.1794	1.1179
Log Likelihood		13520.7357	

Algorithm converged.

The GENMOD Procedure

Analysis Of Initial Parameter Estimates

Parameter	DF	Estimate	Standard Error	Wald 95% Confidence Limits	Chi-Square	Pr > ChiSq

```
   Intercept      1    -19.6388      3.9017    -27.2860    -11.9915      25.33
<.0001
   lnADT          1      1.9505      0.3388      1.2865      2.6145      33.15
<.0001
   Dispersion     1      1.6183      0.1340      1.3760      1.9034
NOTE: The negative binomial dispersion parameter was estimated by maximum likelihood.

                              GEE Model Information

                    Correlation Structure              Independent
                    Subject Effect                  TYP (44 levels)
                    Number of Clusters                          44
                    Correlation Matrix Dimension                 8
                    Maximum Cluster Size                         8
                    Minimum Cluster Size                         3

      Algorithm converged.

                         Analysis Of GEE Parameter Estimates
                          Empirical Standard Error Estimates

                           Standard   95% Confidence
            Parameter Estimate    Error       Limits            Z Pr > |Z|

            Intercept -19.6388   5.9541 -31.3086  -7.9691   -3.30   0.0010
            lnADT        1.9505   0.5129   0.9453   2.9557    3.80   0.0001

                        Wald Statistics For Type 3 GEE Analysis

                                               Chi-
                    Source              DF    Square    Pr > ChiSq

                    lnADT                1     14.46        0.0001
```

Install Median Barrier for I/F Crashes

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                              The GENMOD Procedure

                                Model Information

             Data Set                     WORK.DATA26
             Distribution             Negative Binomial
             Link Function                        Log
             Dependent Variable                 Total    Total
             Offset Variable                       DY    DY
             Observations Used                    292

                            Class Level Information

         Class              Levels    Values

         TYP                    44    C1-1 C1-10 C1-2 C1-3 C1-4 C1-5 C1-6 C1-7 C1-8
C1-9
                                      C2-1 C2-10 C2-2 C2-3 C2-4 C2-5 C2-6 C2-7 C2-8
C2-9
                                      C3-1 C3-10 C3-2 C3-3 C3-4 C3-5 C3-6 C3-7 C3-8
C3-9
                                      C4-1 C4-10 C4-2 C4-3 C4-4 C4-5 C4-6 C4-7 C4-8
C4-9
                                      T1-1 T2-1 T3-1 T4-1
         Treatment               2    C T
         Construction            1    N
```

CNTY	5	CUY(12) DEL(6) FRA(6) HAM(8) SUM(4)
MCL	1	2
SYS_CL	2	I M
ACS	2	F L
FC	2	11 12

Parameter Information

Parameter	Effect
Prm1	Intercept
Prm2	lnADT
Prm3	Midpoint

Criteria For Assessing Goodness Of Fit

Criterion	DF	Value	Value/DF
Deviance	289	323.5547	1.1196
Scaled Deviance	289	323.5547	1.1196
Pearson Chi-Square	289	333.1521	1.1528
Scaled Pearson X2	289	333.1521	1.1528
Log Likelihood		2291.9342	

Algorithm converged.

The GENMOD Procedure

Analysis Of Initial Parameter Estimates

Parameter	DF	Estimate	Standard Error	Wald 95% Confidence Limits		Chi-Square	Pr > ChiSq
Intercept	1	-20.7886	3.9369	-28.5048	-13.0724	27.88	<.0001
lnADT	1	2.0602	0.3449	1.3842	2.7362	35.68	<.0001
Midpoint	1	-0.0005	0.0001	-0.0007	-0.0003	19.80	<.0001
Dispersion	1	1.5766	0.1596	1.2929	1.9226		

NOTE: The negative binomial dispersion parameter was estimated by maximum likelihood.

GEE Model Information

Correlation Structure	Independent
Subject Effect	TYP (44 levels)
Number of Clusters	44
Correlation Matrix Dimension	8
Maximum Cluster Size	8
Minimum Cluster Size	3

Algorithm converged.

Analysis Of GEE Parameter Estimates
Empirical Standard Error Estimates

Parameter	Estimate	Standard Error	95% Confidence Limits		Z	Pr > |Z|
Intercept	-20.7886	6.9184	-34.3483	-7.2289	-3.00	0.0027
lnADT	2.0602	0.6055	0.8734	3.2470	3.40	0.0007
Midpoint	-0.0005	0.0001	-0.0007	-0.0002	-3.77	0.0002

Wald Statistics For Type 3 GEE Analysis

Source	DF	Chi-Square	Pr > ChiSq
lnADT	1	11.58	0.0007
Midpoint	1	14.23	0.0002

Remove/Relocate Fixed Object for Total Crashes

TYP	Duration	Construction	ADT	ptotal	Cy	Total	V(count)	Alpha	EB lambda	V(EB)	Projected Count	V(PC)	
T1-1	365	N	1212	1.35	1.00	1	1.83	0.74	1.26	0.33	1.26	0.11	
T1-1	366	N	1252	1.36	1.00	1	1.84	0.74	1.27	0.33			
T1-1	365	N	1298	1.36	1.00	1	1.84	0.74	1.27	0.33			
T1-1	31	Y	1648	0.12	0.09	0	0.12	0.97	0.12	0.00			
T1-1	334	A	1341	1.25	0.92	1	1.65	0.76	1.19	0.29	1.16	0.09	
T1-1	365	A	1384	1.37	1.01	0	1.85	0.74	1.01	0.26	1.27	0.11	
T1-1	366	A	1423	1.37	1.01	1	1.86	0.74	1.27	0.33	1.28	0.11	
T2-1	365	N	9360	9.37	1.00	24	32.15	0.29	19.74	13.99	16.26	3.91	
T2-1	365	N	9015	9.13	0.97	17	30.79	0.30	14.67	10.32			
T2-1	365	N	8670	8.91	0.95	15	29.50	0.30	13.16	9.19			
T2-1	122	Y	8323	2.90	0.31	2	5.08	0.57	2.51	1.08			
T2-1	244	A	8325	5.79	0.62	8	14.51	0.40	7.12	4.28	10.06	1.50	
T2-1	365	A	7980	8.42	0.90	7	26.83	0.31	7.45	5.11	14.61	3.16	
T2-1	365	A	7635	8.17	0.87	8	25.48	0.32	8.05	5.47	14.17	2.97	
T3-1	365	N	4474	7.89	1.00	6	24.04	0.33	6.62	4.45	7.89	1.75	
T3-1	365	N	4760	7.99	1.01	10	24.57	0.33	9.35	6.31			
T3-1	366	N	5032	8.11	1.03	8	25.18	0.32	8.03	5.45			
T3-1	365	Y	5333	8.18	1.04	11	25.55	0.32	10.10	6.87			
T3-1	365	Y	5620	8.27	1.05	9	26.03	0.32	8.77	5.98			
T3-1	123	Y	5905	2.82	0.36	3	4.88	0.58	2.89	1.22			
T3-1	242	A	5905	5.54	0.70	3	13.52	0.41	4.04	2.38	5.55	0.86	
T3-1	366	A	6176	8.46	1.07	10	27.06	0.31	9.52	6.54	8.47	2.02	
T3-1	365	A	6480	8.52	1.08	2	27.37	0.31	4.03	2.78	8.53	2.04	
T4-1	365	N	1026	0.23	1.00	0	0.24	0.94	0.22	0.01	0.22	0.00	
T4-1	365	N	1035	0.23	1.01	0	0.24	0.94	0.22	0.01			
T4-1	366	N	1040	0.23	1.01	0	0.25	0.94	0.22	0.01			
T4-1	31	Y	1048	0.02	0.09	1	0.02	0.99	0.02	0.00			
T4-1	334	A	1043	0.21	0.93	0	0.22	0.95	0.20	0.01	0.20	0.00	
T4-1	365	A	1061	0.23	1.02	0	0.25	0.94	0.22	0.01	0.22	0.00	
	3711				Actual	40	40.00	6.32	44.10		65.51	12.88	3.59
									4.34	theta	0.61		
	4383								76.01	bias	1.00	Variance	Std Error
					Dispersion		0.26		6.33	Unbiased	0.61	0.01	0.10
									0.69				
Summary of CRF Calculation for Total Crashes										**CRF**	**39.13**		**10.16**

Remove/Relocate Fixed Object for Injury/Fatal Crashes

TYP	Construction	ADT	ptotal	Cy	Total	V(count)	Alpha	EB lambda	V(EB)	Projected Count	V(PC)	
T1-1	N	1212	0.74	1.00	0	0.84	0.88	0.65	0.08	0.65	0.03	
T1-1	N	1252	0.75	1.02	0	0.86	0.87	0.66	0.08			
T1-1	N	1298	0.76	1.03	0	0.87	0.87	0.66	0.08			
T1-1	Y	1648	0.07	0.10	0	0.07	0.99	0.07	0.00			
T1-1	A	1341	0.70	0.95	1	0.80	0.88	0.74	0.09	0.62	0.02	
T1-1	A	1384	0.78	1.06	0	0.89	0.87	0.68	0.09	0.68	0.03	
T1-1	A	1423	0.79	1.07	0	0.91	0.87	0.69	0.09	0.69	0.03	
T2-1	N	9360	5.02	1.00	17	9.83	0.51	10.88	5.32	8.34	1.37	
T2-1	N	9015	4.94	0.98	9	9.61	0.51	6.91	3.36			
T2-1	N	8670	4.87	0.97	9	9.38	0.52	6.86	3.30			
T2-1	Y	8323	1.60	0.32	1	2.09	0.77	1.46	0.34			
T2-1	A	8325	3.20	0.64	6	5.15	0.62	4.26	1.62	5.32	0.56	
T2-1	A	7980	4.71	0.94	5	8.93	0.53	4.84	2.29	7.82	1.21	
T2-1	A	7635	4.62	0.92	5	8.70	0.53	4.80	2.25	7.68	1.16	
T3-1	N	4474	4.86	1.00	2	9.35	0.52	3.48	1.67	4.87	0.77	
T3-1	N	4760	4.98	1.03	6	9.71	0.51	5.48	2.67			
T3-1	N	5032	5.11	1.05	7	10.08	0.51	6.04	2.98			
T3-1	Y	5333	5.21	1.07	8	10.40	0.50	6.60	3.29			
T3-1	Y	5620	5.33	1.10	4	10.74	0.50	4.66	2.35			
T3-1	Y	5905	1.83	0.38	1	2.47	0.74	1.62	0.42			
T3-1	A	5905	3.60	0.74	1	6.08	0.59	2.54	1.04	3.62	0.43	
T3-1	A	6176	5.55	1.14	4	11.42	0.49	4.75	2.44	5.57	1.01	
T3-1	A	6480	5.64	1.16	1	11.72	0.48	3.24	1.68	5.66	1.04	
T4-1	N	1026	0.13	1.00	0	0.13	0.98	0.12	0.00	0.12	0.00	
T4-1	N	1035	0.13	1.00	0	0.13	0.98	0.12	0.00			
T4-1	N	1040	0.13	1.01	0	0.13	0.98	0.13	0.00			
T4-1	Y	1048	0.01	0.09	1	0.01	1.00	0.01	0.00			
T4-1	A	1043	0.12	0.92	0	0.12	0.98	0.11	0.00	0.11	0.00	
T4-1	A	1061	0.13	1.01	0	0.13	0.98	0.13	0.00	0.13	0.00	
				Actual	23	23	4.80	26.78		37.90	5.49	2.34
								2.63	theta	0.61		
								41.99	bias	1.00	Variance	Std Error
				Dispersion		0.19		3.50	Unbiased	0.60	0.02	0.13
								0.75				

Summary of CRF Calculation for Injury and Fatality Crashes	CRF	39.55	13.10

Install Median Barrier for Total Crashes

TYP	Duration	Construction	ADT	ptotal	Cy	Total	V(count)	Alpha	EB lambda	V(EB)	Projected Count	V(PC)	
T1-1	365	N	117000	25.44	1.00	0	1072.92	0.02	0.60	0.59	3.44	1.09	
T1-1	366	N	118682	26.15	1.03	4	1132.59	0.02	4.51	4.41			
T1-1	365	N	121014	26.97	1.06	5	1203.87	0.02	5.49	5.37			
T1-1	365	Y	123021	27.74	1.09	8	1273.44	0.02	8.43	8.25			
T1-1	365	Y	125028	28.53	1.12	5	1345.83	0.02	5.50	5.38			
T1-1	213	Y	127034	17.11	0.67	3	491.06	0.03	3.49	3.37			
T1-1	153	A	129041	12.63	0.50	1	270.77	0.05	1.54	1.47	1.71	0.27	
T1-1	365	A	131050	30.95	1.22	10	1580.62	0.02	10.41	10.21	4.18	1.61	
T1-1	365	A	133057	31.77	1.25	9	1664.96	0.02	9.43	9.25	4.29	1.70	
T2-1	366	N	73932	11.55	1.00	52	227.34	0.05	49.95	47.41	48.23	13.94	
T2-1	365	N	78191	12.69	1.10	69	273.10	0.05	66.38	63.30			
T2-1	365	N	82247	13.84	1.20	44	323.96	0.04	42.71	40.89			
T2-1	365	Y	86302	15.04	1.30	3	381.23	0.04	3.48	3.34			
T2-1	366	Y	90111	16.25	1.41	9	443.68	0.04	9.27	8.93			
T2-1	365	Y	94414	17.57	1.52	1	516.96	0.03	1.56	1.51			
T2-1	153	Y	98469	7.92	0.69	0	109.38	0.07	0.57	0.53			
T2-1	212	A	102524	11.76	1.02	0	235.70	0.05	0.59	0.56	49.14	14.47	
T2-1	365	A	106581	21.66	1.88	0	780.68	0.03	0.60	0.58	90.46	49.04	
T3-1	365	N	91057	8.58	1.00	2	127.75	0.07	2.44	2.28	1.39	0.40	
T3-1	365	N	95630	9.34	1.09	1	150.46	0.06	1.52	1.42			
T3-1	365	N	100202	10.12	1.18	0	175.96	0.06	0.58	0.55			
T3-1	366	Y	104489	10.91	1.27	5	203.62	0.05	5.32	5.03			
T3-1	365	Y	109347	11.77	1.37	5	236.00	0.05	5.34	5.07			
T3-1	120	Y	113920	4.15	0.48	2	32.07	0.13	2.28	1.98			
T3-1	245	A	104155	7.26	0.85	3	92.67	0.08	3.33	3.07	1.18	0.29	
T4-1	365	N	82470	11.13	1.00	28	211.46	0.05	27.11	25.69	21.32	6.51	
T4-1	365	N	84180	11.53	1.04	27	226.58	0.05	26.21	24.88			
T4-1	365	N	85890	11.94	1.07	13	242.45	0.05	12.95	12.31			
T4-1	366	Y	87361	12.32	1.11	11	258.10	0.05	11.06	10.53			
T4-1	365	Y	89310	12.77	1.15	4	276.56	0.05	4.40	4.20			
T4-1	120	Y	91019	4.34	0.39	0	34.78	0.12	0.54	0.47			
T4-1	245	A	91019	8.86	0.80	0	135.75	0.07	0.58	0.54	16.97	4.12	
								SE					
	1950				ACTUAL	23	23.00	4.80	26.49		167.91	71.49	
									4.96	theta	0.14		
	4382				Dispersion		1.62		240.46	bias	1.00	Variance	Std Error
									20.03	Unbiased	0.14	0.00	0.03
									0.25				

Summary of CRF Calculation for Total Crashes **CRF** **86.34** **2.92**

Install Median Barrier for Injury/fatal Crashes

TYP	Duration	Construction	ADT	ptotal	Cy	Total	V(count)	Alpha	EB lambda	V(EB)	Projected Count	V(PC)	
T1-1	365	N	117000	13.79	1.00	0	313.58	0.04	0.61	0.58	1.70	0.59	
T1-1	366	N	118682	12.51	0.91	1	259.23	0.05	1.56	1.48			
T1-1	365	N	121014	11.39	0.83	2	215.95	0.05	2.50	2.36			
T1-1	365	Y	123021	10.35	0.75	5	179.13	0.06	5.31	5.00			
T1-1	365	Y	125028	9.39	0.68	1	148.52	0.06	1.53	1.43			
T1-1	213	Y	127034	5.11	0.37	0	46.21	0.11	0.56	0.50			
T1-1	153	A	129041	3.54	0.26	0	23.32	0.15	0.54	0.46	0.44	0.04	
T1-1	365	A	131050	7.94	0.58	3	107.45	0.07	3.37	3.12	0.98	0.20	
T1-1	365	A	133057	7.20	0.52	0	88.94	0.08	0.58	0.54	0.89	0.16	
T2-1	366	N	73932	5.53	1.00	27	53.71	0.10	24.79	22.24	27.64	8.50	
T2-1	365	N	78191	5.37	0.97	36	50.83	0.11	32.76	29.30			
T2-1	365	N	82247	5.18	0.94	25	47.51	0.11	22.84	20.35			
T2-1	365	Y	86302	4.98	0.90	1	44.04	0.11	1.45	1.29			
T2-1	366	Y	90111	4.75	0.86	5	40.37	0.12	4.97	4.39			
T2-1	365	Y	94414	4.54	0.82	0	37.05	0.12	0.56	0.49			
T2-1	153	Y	98469	1.88	0.34	0	7.43	0.25	0.47	0.35			
T2-1	212	A	102524	2.62	0.47	0	13.47	0.19	0.51	0.41	13.11	1.91	
T2-1	365	A	106581	4.38	0.79	0	34.64	0.13	0.55	0.48	21.90	5.34	
T3-1	365	N	91057	3.43	1.00	1	22.01	0.16	1.38	1.16	1.14	0.33	
T3-1	365	N	95630	3.30	0.96	1	20.50	0.16	1.37	1.15			
T3-1	365	N	100202	3.17	0.92	0	18.96	0.17	0.53	0.44			
T3-1	366	Y	104489	3.02	0.88	4	17.35	0.17	3.83	3.16			
T3-1	365	Y	109347	2.87	0.84	2	15.90	0.18	2.16	1.77			
T3-1	120	Y	113920	0.94	0.27	1	2.31	0.40	0.97	0.58			
T3-1	245	A	104155	1.53	0.45	2	5.22	0.29	1.86	1.32	0.51	0.07	
T4-1	365	N	82470	4.43	1.00	14	35.40	0.13	12.80	11.20	11.92	3.75	
T4-1	365	N	84180	4.05	0.91	12	29.98	0.14	10.93	9.45			
T4-1	365	N	85890	3.71	0.84	10	25.37	0.15	9.08	7.75			
T4-1	366	Y	87361	3.38	0.76	2	21.38	0.16	2.22	1.87			
T4-1	365	Y	89310	3.09	0.70	1	18.16	0.17	1.36	1.13			
T4-1	120	Y	91019	0.97	0.22	0	2.44	0.40	0.38	0.23			
T4-1	245	A	91019	1.85	0.42	0	7.28	0.25	0.47	0.35	4.99	0.66	
								SE					
	1950					5	5.00	2.24	7.89		42.82	8.11	2.85
									1.48	theta	0.12		
	4382								121.14	bias	1.00	Variance	Std Error
									10.09	Unbiased	0.12	0.00	0.05
									0.15				
			Summary of CRF Calculation for Injury and Fatality Crashes										
										CRF	**88.37**		5.23